§ 4.—*Spectra of Luminous Gases.*

It was first shown by Kirchhoff that glowing gases emit light of the same wave-length, and therefore also of the same period, as that which they absorb.

In the modern theory of gases it is assumed that the molecules of a luminous gas move over a certain distance, the length of the "free path," in straight lines, until they collide with other molecules, or with the sides of the containing vessel, when they move off rectilinearly in another direction.

At every collision the molecule is subjected to an elastic impulse in a direction passing through its centre, causing internal elastic vibrations. The periods of these vibrations could, on the analogy of a corresponding problem in the theory of elasticity, be calculated from a transcendental equation, if the interior of the molecule were uniformly filled with matter; according to Thomson's theory of molecular structure they are determined *a priori*, being the critical periods of the molecule. In fact, during the collisions the external shells only are in contact, but the surrounding ether remains unaffected, and therefore the external vibrations must be of such a nature that $\xi = 0$ (§ 1), which is the condition determining the critical periods. But according to § 1 these periods determine the wave-length of the light absorbed. Thus Kirchhoff's law is a consequence of the theory.

It has hitherto been assumed that the vibrations in a molecule, arising from the collisions, take place along a fixed diameter, and therefore that the vibrations due to one encounter are not disturbed by a later one in another direction. If the temperature or the density of the gas is so great that the encounters follow one another very rapidly, the investigation of § 1 is no longer applicable, and light-waves of other than the critical periods will be emitted. If a second encounter takes place only after the vibration due to the first has nearly subsided, the period of the emitted light will only differ slightly from a critical period. As the density and temperature increase, the bright lines will therefore gradually increase in width.[1] If a molecule receives impulses in different directions in rapid succession, very few of the vibrations will have the critical periods, and therefore the dark spaces between the bright lines will ultimately disappear, and the spectrum become continuous, as is well known to be experimentally true.

§ 5.—*Applications to the Theory of Heat.*

It will be of interest to see what explanation Thomson's molecular hypothesis can give of the manner in which the velocity of gaseous molecules can be increased by the action of heat, as has been assumed in what precedes.

The energy due to the internal molecular vibrations cannot possibly exceed a definite maximum value, for the amplitudes and therefore the velocities of the centres of the shells must have fixed upper limits, since the shells must remain one within the other. This maximum may be attained either for vibrations of a single critical period, or of all the critical periods. Suppose this maximum value to have been nearly reached, then any further disturbance of the internal equilibrium, tending to increase the amplitude of motion of one of the centres beyond the maximum value possible while the centre of gravity remains fixed, will necessarily displace the centre of gravity, whether the disturbance be due to a wave of light or to a mechanical impulse.

This leads to the general and fundamental proposition that "A molecule will begin to move as soon as the energy of its internal vibrations has attained its maximum value, supposing the external influences to which the attainment of the maximum is due continue to act.[2]

The internal equilibrium of a molecule may be disturbed either by light or heat, the disturbance in the case of light being due to its action on the critical periods of the molecule. A medium will therefore be heated when traversed by light-rays; the rays of the critical periods set the molecular shells in vibration, and when the internal energy has reached its maximum value, the centres of gravity of the molecules will begin to move, and this motion will be perceived as heat.

The energy of internal motions therefore accounts for a portion of the internal work of the mechanical theory of heat.[1]

The external work is effected by the motion of the centres of gravity of the atoms, and this takes place in different and known ways in solid, liquid, and gaseous bodies. Heat may act on a medium either by radiation or conduction. Radiant heat differs from light only in its action on our senses, so that what has been said about light will apply also to radiant heat. In the case of conduction of heat the process is exactly the reverse. The external work of the medium emitting the heat will be transmitted directly to the medium receiving it by contact—that is, by collisions of molecules.[2]

The disturbance of the internal equilibrium of the molecules is here merely a secondary effect, but in this case also the internal energy will gradually increase to the maximum value.[3]

The emission of light by a sufficiently heated solid is explained as in the case of gases, but the spectrum in the case of the solid is continuous.

Just as the action of heat may produce such violent molecular motion as to cause the emission of all possible kinds of light, so the action of light may produce a molecular motion giving rise to a special kind of light. This will only happen, however, when the molecule (owing to specially favourable values of the constants c_i and m_i) is specially susceptible to some among its critical periods. In this way the phenomenon of fluorescence may be explained. G. W. DE TUNZELMANN.

(*To be continued.*)

SOCIETIES AND ACADEMIES.

LONDON.

Royal Society, June 21.—"On the Determination of the Photometric Intensity of the Coronal Light during the Solar Eclipse of August 28–29, 1886. Preliminary Notice." By Captain W. de W. Abney, C.B., R.E., F.R.S., and T. F. Thorpe, Ph.D., F.R.S.

Attempts to measure the brightness of the corona were made by Pickering in 1870, and by Langley and Smith, independently, in 1878, with the result of showing that the amount of emitted light as observed at various eclipses, may vary within comparatively wide limits. These observations have been discussed by Harkness ("Washington Observations for 1876," Appendix III.) and they are again discussed in the present paper. Combining the observations, it appears that the total light of the corona in 1878 was 0·072 of that of a standard candle at 1 foot distance, or 3·8 times that of the full moon, or 0·0000069 of that of the sun. It further appears from the photographs that the coronal light varied inversely as the square of the distance from the sun's limb. Probably the brightest part of the corona was about 15 times brighter than the surface of the full moon, or 37,000 times fainter than the surface of the sun.

The instruments employed by the authors in the measurement of the coronal light on the occasion of the solar eclipse of August 28–29, 1886, were three in number. The first was constructed to measure the comparative brightness of the corona at different distances from the moon's limb. The second was designed to measure the total brightness of the corona, excluding as far as possible the sky effect. The third was intended to measure the brightness of the sky in the direction of the eclipsed sun. In all three methods the principle of the Bunsen photometric method was adopted, and in each the comparison-light was a small glow-

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[1] This result may be expressed by saying that the characteristic constant c_i of the molecule is a function of the temperature. It is preferable to regard the ideal spectrum, whether due to emission or absorption, as something definitely fixed; external circumstances merely assisting or hindering its formation.

[2] Sir W. Thomson also points out ("Lectures," p. 280) that a considerable increase in the internal vibrations of a molecule must set it in motion, and therefore cause a production of heat.

[1] The discrepancies occurring in the determination of the atomic weights of gases may therefore be explained by assuming that internal work is done by the motions of the atoms, instead of assuming, as would otherwise be necessary, that the internal work is only done by the motions of the molecules and a decrease in the attractive force between them. For "motion of the atoms" we should have to substitute "motion of the inner spherical shells."

[2] For the method of deducing the differential equation of heat-conduction from these considerations, see F. Neumann, "Vorlesungen über die Theorie der Elasticität," § 59.

[3] Dulong's law of atomic heat gives some information respecting the relative value of this maximum. This law states that the quantity of internal work due to heating is approximately the same, at any rate when in the gaseous state, for elementary bodies which are ordinarily solid or liquid, a given number of atoms always requiring the same quantity of heat to produce a given rise of temperature. It follows, then, that for these elements the maximum internal energy is very nearly the same. Carbon, silicon, sulphur, and phosphorus behave exceptionally in this, as in many other respects, and the law is not generally true for the elements which are ordinarily gaseous. Since the maximum value of the internal energy depends on the diameter of the molecule, as well as on the constants c_i and m_i, it may perhaps be concluded that the diameter of the molecules of these elements are approximately equal.

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lamp previously standardized by a method already described by one of the authors in conjunction with General Festing. In the first two methods the photometer-screen was fixed, the intensity of the comparison-light being adjusted by one of Varley's carbon resistances; in the third the glow-lamp was maintained at a constant brightness, the position of the screen being adjusted along a graduated photometer bar, as in the ordinary Bunsen method. Full details of the construction of the several pieces of apparatus are given in the original paper.

The observations during the eclipse were made at Hog Island, a small islet at the south end of Grenada, in lat. 12° 0′ N. and long. 61° 43′ 45″ W., with the assistance of Captain Archer and Lieutenants Douglas and Bairnsfather of H.M.S. *Fantôme*. The duration of totality at the place of observation was about 230 seconds, but measurements were possible only during 160 seconds, at the expiration of which time the corona was clouded over. A careful discussion of the three sets of measurements renders it almost certain that the corona was partially obscured by haze during the last 100 seconds that it was actually visible. Selecting the observations made during the first minute, which are perfectly concordant, the authors obtain six measurements of the photometric intensity of the coronal light at varying distances from the sun's limb, from which they are able to deduce a first approximation to the law which connects the intensity of the light with the distance from the limb.

The observations with the integrating apparatus made independently by Lieutenants Douglas and Bairnsfather, agree very closely. It appears from their measurements that the total light of the corona in the 1886 eclipse was—

Douglas	0·0123	standard candle
Bairnsfather	0·0125	,,
Mean . . .	0·0124	,,

at a distance of 1 foot.

In comparing these observations with those made during the 1878 eclipse, it must be remembered that the conditions of observation on the two occasions were widely different. The observations in the West Indies were made at the sea's level, in a perfectly humid atmosphere and with the sun at no greater altitude than 19°. Prof. Langley, in 1878, observed from the summit of Pike's Peak in the Rocky Mountains at an altitude of 14,000 feet, in a relatively dry atmosphere and with the sun at an altitude of 39°.

From observations on the transmission of sunlight through the earth's atmosphere (Abney, Phil. Trans., A, clxxviii (1887), 251) one of the authors has developed the law of the extinction of light, and, by applying the necessary factors, it is found that the intensity of the light during the 1886 eclipse, as observed at Grenada, is almost exactly half of that of which would have been transmitted from a corona of the same intrinsic brightness when observed at Pike's Peak. Hence to make the observations of Prof. Langley comparable with those of the authors, the numbers denoting the photometric intensity of the corona in 1878 must be halved. The result appears, therefore, that whereas in 1878 the brightness of the corona was 0·0305 of a standard candle at a distance of 1 foot, in 1886 it was only 0·0124 of a candle at the same distance. Several of the observers of the West Indian eclipse (including one of the authors) were also present at the eclipse of 1878, and they concur in the opinion that the darkness during the 1886 eclipse was very much greater than in that of 1878. The graduations on instruments, chronometer faces, &c., which were easily read in 1878, were barely visible in 1886. In explanation of this difference in luminous intensity it must not be forgotten that the 1878 eclipse was not very far removed from a period of maximum disturbance, whereas in 1886 we were approaching a period of minimum disturbance.

PARIS.

Academy of Sciences, August 6.—M. Janssen, President, in the chair.—Fresh experiments on the fixation of nitrogen by certain vegetable soils and plants, by M. Berthelot. These researches, made with three different kinds of argillaceous soil and with plants of the leguminous family, fully confirm the results of previous studies. The fundamental fact that both plants and soil absorb nitrogen under the most diverse conditions is now placed beyond all reasonable doubt. So certain does the author consider this conclusion, that he declines all further discussion on the subject of certain recent negative experiments carried out under defective conditions.—On a recent change in the views of meteorologists regarding gyratory movements, by M. H. Faye. The author claims that the new school of meteorologists, represented by Messrs. Loomis, Meldrum, and Douglas Archibald (see NATURE, June 14, p. 149), shows a tendency to accept his conclusions on certain points at issue. These authorities already admit that the cyclonic movements originate, not on the surface of the earth as had long been contended, but in the higher atmospheric regions, a position irreconcilable with their hypothesis of an ascending, but in full accordance with M. Faye's view of a descending motion.—Summary of the solar observations made at the Royal Observatory of the Collegio Romano during the second quarter of 1888, by M. P. Tacchini. These observations show an increase of the solar spots in May and June, and of the protuberances in April. The general inference is that the relation between these two orders of phenomena is less intimate than might be supposed from previous observations.—On a new apparatus for studying the friction of fluids, by M. M. Couette. This method, differing from those of Coulomb and Poiseuille hitherto employed, is based on the principle indicated by Dr. Margules in 1881 (*Wiener Berichte*, 2nd series, vol. lxxxiii. p. 588). It has the advantage of controlling Navier's theory for very thin tubes and slow discharge, and of operating on gases at constant pressure.—On levulose, by MM. E. Jungfleisch and L. Grimbert.—On the malonates of potassa and soda, by M. G. Massol.—On the hydrates of methane and ethylene, by M. Villard.—On experimental tetanus, by M. Rietsch.—M. A. de Schulten describes a process by which he has succeeded in producing the crystallized anhydrous sulphates of cadmium and zinc (artificial zincosite); and M. A. Poincaré shows how are produced the barometric movements corresponding to the displacement of the moon in declination.—The present number contains the text of the address delivered by the President, M. Janssen, at the unveiling of the monument raised by the city of Tours to the memory of General Meusnier on July 29, 1888.

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